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Thompson

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[54] **END SEAL FOR TURBINE BLADE BASES**

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[51] **Int. Cl.**[3] **F01D 5/30**

[52] **U.S. Cl.** ..... **416/193 A;** 416/95; 416/220 R

[58] **Field of Search** ..... 416/220 R, 95, 193 A, 416/221

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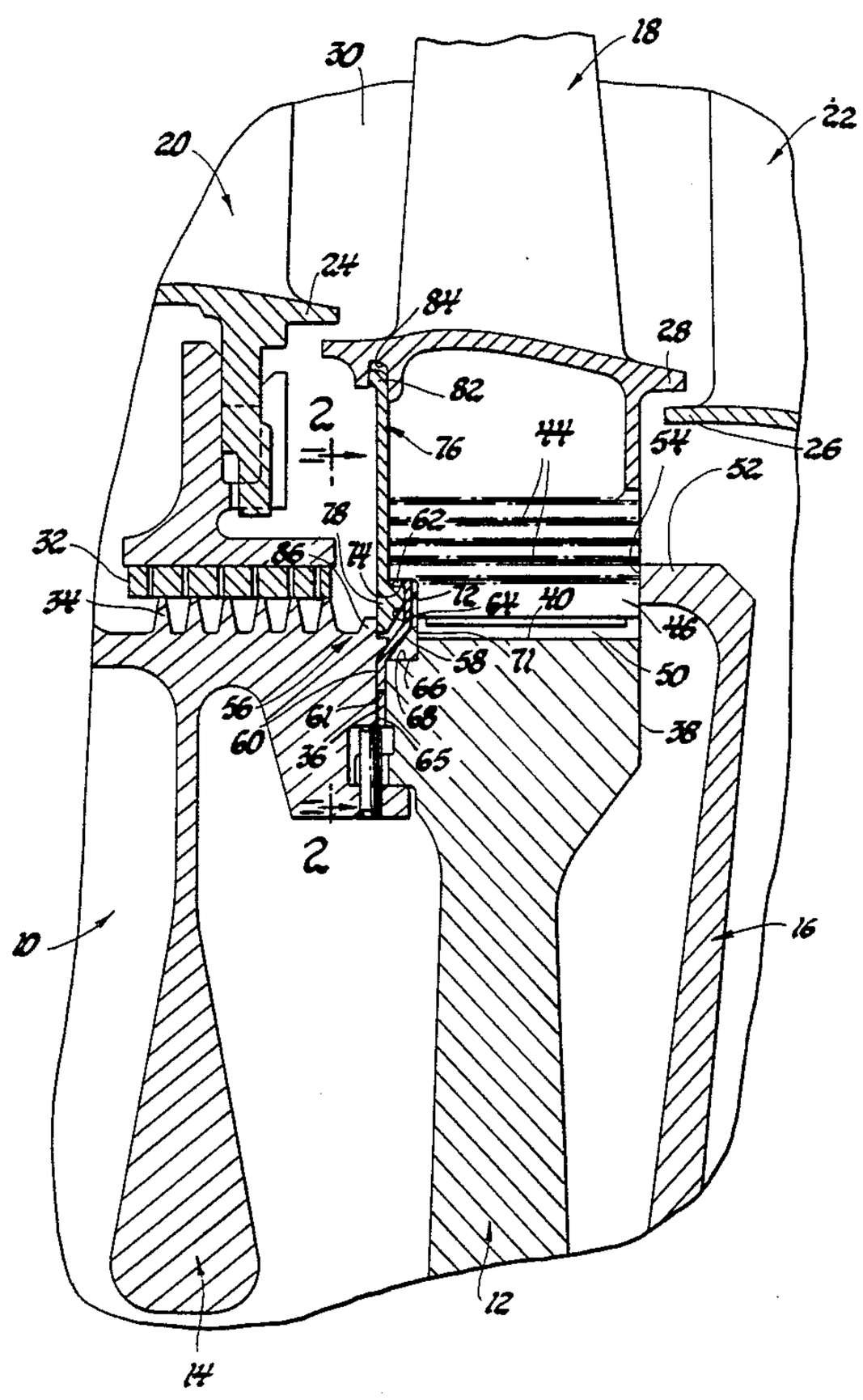
[57] **ABSTRACT**

An end seal for cooling air manifolds below the bases of a stage of air cooled turbine blades on a turbine wheel, the end seal including a seal ring having an annular planar portion abutting an end face of the turbine wheel inboard of the air manifolds and a right cylindrical flange perpendicular to the planar portion and underlying a corresponding cylindrical shoulder on the wheel and on the blade bases outboard of the air manifolds, and a plurality of end plates on the wheel having lugs underlying the cylindrical flange. The planar portion is axially clamped to the wheel to define a 360° inboard seal while centrifugal forces developed by the end plates during rotation of the wheel cause the lugs to radially clamp the cylindrical flange against the cylindrical shoulder on the wheel and blade bases to define a 360° outboard seal.

3 Claims, 2 Drawing Figures



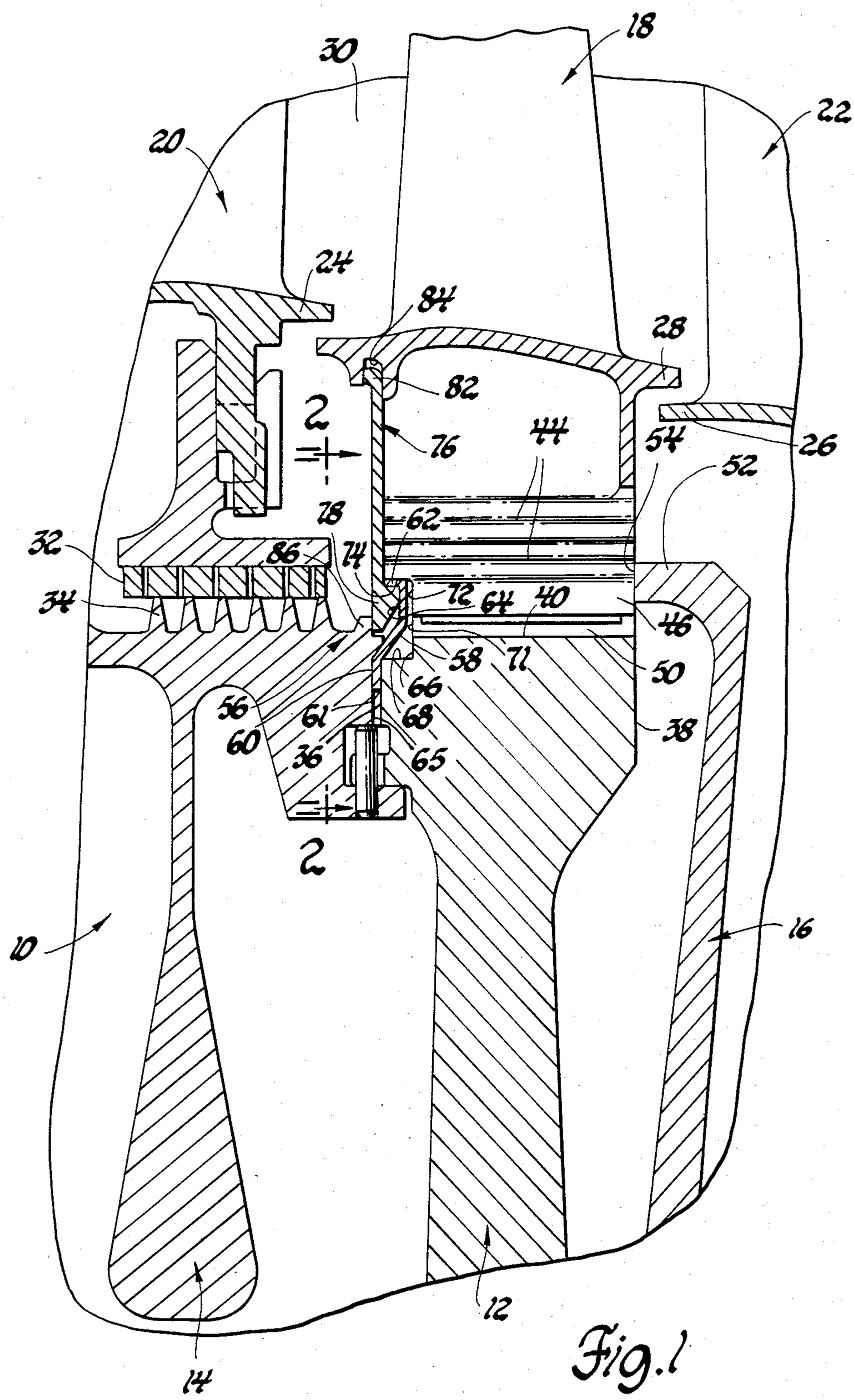

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Fig. 1

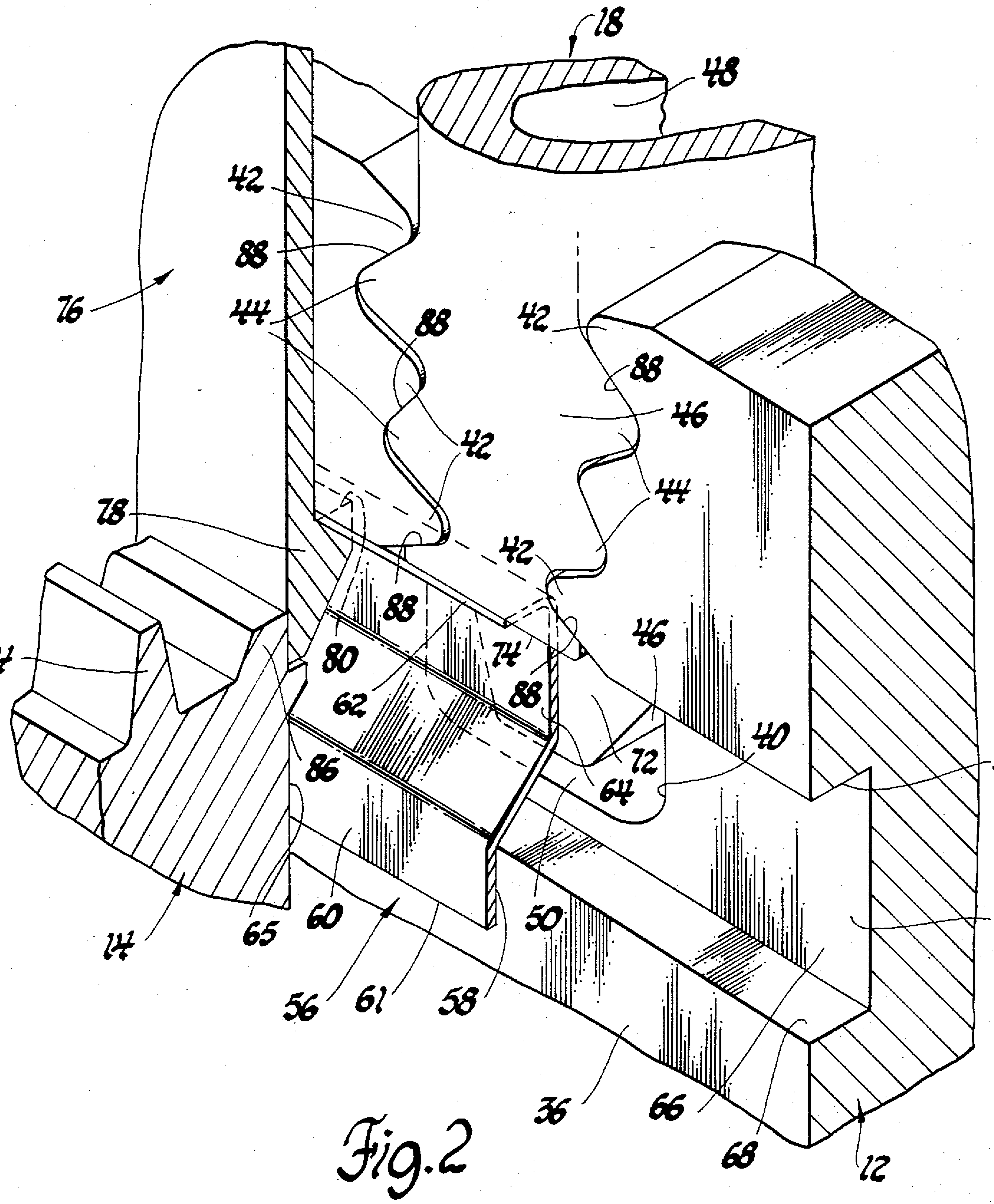
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Fig.2

END SEAL FOR TURBINE BLADE BASES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to gas turbine engine rotors having air cooled turbine blades and, more particulary, to end seals at the turbine blade bases.

2. Description of the Prior Art

With more emphasis on fuel economy and more extensive use of air cooled turbine blades, minimizing the loss of cooling air from blade delivery circuits is an important design consideration. One very difficult area to seal is the turbine blade-turbine wheel attachment interface. Typically, cooling air is delivered into a clearance slot or manifold in the wheel inboard of the individual blade attachments from which it flows into the blade internal cooling cavities. The typical fir tree attachment on the blade base fits snugly into the wheel lugs and under centrifugal loading seals tightly against leakage. However, due to manufacturing tolerances the axial length of the blade base and wheel may differ from blade to blade and wheel to wheel. The result is leakage at the end of the air manifold between the blade or wheel and the cover plate normally installed to prevent such leakage. An end seal according to this invention reduces cooling air loss attributable to manufacturing tolerances between the blade base and the turbine wheel.

SUMMARY OF THE INVENTION

Accordingly, the primary feature of this invention is that it provides a new and improved end seal at the base of an air cooled turbine blade which minimizes cooling air leakage due to differences between the axial lengths of the turbine blades and the turbine wheel resulting from manufacturing tolerances. Another feature of this invention resides in the provision in the new and improved end seal of a disc which overlaps the bases of the air cooled blades and in the provision of axial clamping means for clamping the disc against the side of the turbine wheel to effect a 360° inboard seal and centrifugally actuated radial clamping means for clamping the disc to the turbine wheel and to the individual blade bases to effect a 360° outboard seal. Still another feature of this invention resides in the provision in the new and improved end seal of a disc having an annular planar portion for sealing against the side of the turbine wheel and an integral right circular flange underlying a cylindrical shoulder on the turbine wheel and corresponding shoulders on each of the turbine blade bases and in the provision of end plates with lugs underlying the cylindrical flange which lugs press the flange against the wheel and the blade bases under the influence of centrifugal force as the wheel rotates. These and other features of this invention will be readily apparent from the following specification and from the drawings wherein:

FIG. **1** is a fragmentary elevational view, partly in section, of a gas turbine rotor including air cooled turbine blades and an end seal according to this invention; and

FIG. **2** is a partially broken away perspective view taken generally along the plane indicated by lines **2—2** in FIG. **1** and showing the end seal according to this invention.

Referring now to FIG. **1** of the drawings, a gas turbine engine rotor **10** includes a turbine wheel **12**, a spacer **14**, and an aft cover plate **16**. The turbine wheel

12 carries a plurality of air cooled turbine blades forming one stage of turbine blades of the engine, only a single turbine blade **18** being illustrated in FIGS. **1** and **2**, which stage of blades is disposed between an upstream stage of stator vanes **20** and a downstream stage of stator vanes **22**. The stator vanes **20** are mounted on a casing, not shown, of the gas turbine engine and direct motive fluid at the turbine blades while the stator vanes **22** are similarly mounted on the casing and direct the motive fluid at the next succeeding stage of turbine blades, not shown. Each of the stator vanes **20** includes a platform **24** and each of the stator vanes **22** includes a platform **26** which platforms cooperate with corresponding platforms on the turbine blades, such as a platform **28** on blade **18**, in defining a motive fluid path designated generally **30**. An abradable seal **32** on the stage of stator vanes **20** cooperates with a plurality of circumferential ridges **34** on the spacer **14** in defining a seal across the stage.

Referring now to both FIGS. **1** and **2**, the turbine wheel **12** has an annular upstream face **36** in a transverse plane perpendicular to the axis of rotation of the rotor, an annular downstream face **38** in a similar transverse plane, and a plurality of circumferentially spaced blade retention slots, represented by a retention slot **40**, oriented generally axially between the upstream and downstream faces. The slot **40** is of well known fir tree configuration and includes a plurality of axially extending lugs **42** arranged in pairs on opposite sides of the slot which becomes progressively narrower in the radial inward direction. The lugs **42** receive therebetween a corresponding plurality of lugs **44** on a fir tree base **46** of the turbine blade **18**, the base **46** being slidably inserted into the retention slot **40** through either of the upstream or downstream faces **36** and **38**, respectively.

The turbine blade **18** is air cooled and includes a schematically represented internal passage **48**, FIG. **2**, which communicates with the motive fluid path **30** and a space **50** between the bottom or radially innermost extremity of the slot **40** and the radially innermost extremity of the base **46**, the space **50** being denominated herein as the cooling air manifold. The aft cover plate **16** includes a peripheral flange **52** having an annular face **54** which axially abuts the downstream face **38** of the turbine wheel and blades radially outboard of the cooling air manifold **50** and provides a tight seal against the downstream face. The blades **18** are pushed rearward by aerodynamic pressure back into intimate contact with the aft cover plate face **54** to assure a good seal between the blades and cover plate. The space between aft cover plate **16** and turbine wheel **12** is pressurized by the relatively cool air from the compressor of the engine which cool air circulates into the air manifold **50** from the downstream face **38**, through the internal passages of the turbine blade **18**, and then into the motive fluid path **30**. During passage through the turbine blade, the cooling air maintains the turbine blade at a temperature consistent with maximum blade durability. An end seal according to this invention and designated generally **56** is located at the opposite end of the manifold **50** to prevent escape of cooling air at the upstream face **36** of the turbine wheel.

The end seal **56** includes a seal ring **58** having an annular planar portion **60** disposed in a transverse plane perpendicular to the axis of rotation of the rotor and defining an inside diameter **61** of the seal ring, a right cylindrical flange **62** perpendicular to the plane of pla-

nar portion **60**, and an annular channel portion **64** integral with and interconnecting the planar portion **60** and the flange **62**. The planar portion **60** is tightly captured between the upstream face **36** of the wheel **12** and a side **65** of the spacer **14**, the spacer and wheel being urged together as part of the construction of the rotor itself. In order to accommodate the flange **62** and the channel portion **64**, the turbine wheel **12** has formed in the upstream face **36** thereof an annular groove **66** having an inboard edge **68** at a radial distance from the axis of rotation of the rotor less than the radial distance to the bottom of the groove **40**, an outboard edge **70**, and a bottom **71**. The base **46** of the turbine blade **18**, as well as the corresponding bases of the other turbine blades in the stage, is relieved to maintain the continuity of the groove **66** across the base, the relief providing a transverse face **72** corresponding generally to the bottom **71** of groove **66** and a shoulder **74** perpendicular to the transverse face and corresponding generally to the outboard edge **70** of the groove.

With continued reference to FIGS. **1** and **2**, the end seal **56** further includes a plurality of end plates at the upstream face **36** of the turbine wheel, only a single end plate **76** being shown in the Figures. The end plate **76** is a segment of an annulus spanning a plurality of the turbine blade bases and includes an integral inner lug **78**, an annular shoulder **80** on the lug **78**, and an outer edge **82**. The end plate **76** abuts the upstream face **36** of the turbine wheel with the lug **78** projecting into the channel **64** in the seal ring and the annular shoulder **80** underlying the flange **62** and with the outer edge **82** disposed in appropriate grooves in the turbine blades below the platforms, a groove **84** in the turbine blade **18** being representative, which grooves cooperate in defining an annulus extending around the wheel. The end plate **76** is generally loosely captured in the groove **84** and behind an upstanding retainer **86** on the spacer **14** so that the end plate is free to move radially outward through limited displacement.

Describing now the operation of the end seal **56**, when the gas turbine engine is in operation motive fluid flows downstream in the fluid path **30** and is directed against the turbine blade stage of wheel **12** causing the latter to rotate at high speed. The turbine blade **18** is retained on the wheel by interengagement between the lugs **42** on the wheel and the lugs **44** on the blade base along a plurality of lines of contact **88**, FIG. **2**, extending between the upstream and downstream faces **36** and **38**, respectively. Because of the magnitude of the centrifugal force developed by the blade **18**, the lines of contact **88** form essentially air-tight seals so that the air manifold **50** is sealed longitudinally on opposite sides of the slot **40** at the radially innermost lines of contact **88**.

At the upstream face **36** of the turbine wheel the planar portion **60** of the seal ring **58** is tightly axially clamped between the turbine wheel upstream face and the surface **65** of the spacer **14**. Because the planar portion **60** engages the upstream face **36** through a full 360° of contact radially inboard of the innermost extremity of slot **40**, an inboard airtight seal preventing escape of cooling air from slot **40** around the planar portion is provided. As seen best in FIG. **2**, the radial distance from the axis of rotation of the rotor to the outboard edge **70** of the groove **66** and the shoulder **74** on the blade base **46** at least equals the radial distance to the innermost lines of contact **88** between the lugs **44** and **42** on the base and the turbine wheel, respectively. The flange **62** of the seal ring **58**, underlying the outboard edge **70** and the shoulder **74**, is radially clamped against the outboard edge and the shoulder by the annular shoulder **80** on the end plate **76** which is urged radially outward under the influence of centrifugal force. The centrifugal force developed by the end plate **76** is substantial so that the flange **62** is very tightly pressed against the shoulder **74** and the outboard edge **70** thereby defining an outboard seal across the slot **40** and radially outboard of the manifold **50**. The end plate **76**, in addition to centrifugally energizing the lug **78** to press the shoulder **80** against the flange **62**, also prevents axial passage of motive fluid across the turbine wheel below the platform **28** which could occur due to the pressure drop across the turbine blade stage.

It will be apparent that the foregoing description assumes complete and intimate contact between the flange **62** and the shoulder **74** on the base **46**. However, because manufacturing tolerances are inherent, it may be necessary to locally deform the flange **62** to more fully follow the contour of the shoulder **74** across the slot **40**. Regardless, however, the very substantial centrifugal loading imposed by the end plate **76** through the lug **78** and the shoulder **80** will press the flange against the shoulder **74** and the outboard edge **70** to, at least, significantly reduce cooling air leakage from the air manifold **50**.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a gas turbine rotor assembly including a wheel having a circumferential array of retention slots and a plurality of air cooled blades having bases disposed in respective ones of said retention slots, said bases cooperating with said respective ones of said slots in defining a plurality of manifolds supplied with pressurized air from a first side of said wheel, an end seal for each of said manifolds at a second side of said wheel comprising, a seal ring having an annular planar portion and a cylindrical flange radially outboard of and perpendicular to said planar portion, means for axially clamping said seal ring planar portion against said second side of said wheel with a circle of contact radially inboard of each of said slots so that a 360° inboard seal is defined, means on said wheel and on each of said blade bases defining a continuous radially inwardly facing cylindrical shoulder disposed radially outboard of each of said manifolds, said flange being disposed radially inboard of and adjacent said cylindrical shoulder, and centrifugal clamp means on said wheel engageable on said flange under the influence of centrifugal force during rotation of said wheel to radially clamp said flange against said cylindrical shoulder and thereby provide a 360° seal radially outboard of each of said manifolds.

2. In a gas turbine rotor assembly including a wheel having a circumferential array of retention slots and a plurality of air cooled blades having bases disposed in respective ones of said retention slots, said bases cooperating with said respective ones of said slots in defining a plurality of manifolds supplied with pressurized air from a first side of said wheel, an end seal for each of said manifolds at a second side of said wheel comprising, a seal ring having an annular planar portion and an integral cylindrical flange radially outboard of and perpendicular to said planar portion, means for axially clamping said seal ring planar portion against said second side of said wheel with a circle of contact radially inboard of each of said slots so that a 360° inboard seal is defined, means on said wheel and on each of said

blade bases defining a continuous radially inwardly facing cylindrical shoulder disposed radially outboard of each of said manifolds, said flange being disposed radially inboard of and adjacent said cylindrical shoulder, a plurality of end plates supported on said wheel adjacent said second side for limited centrifugally induced radially outward displacement during rotation of said wheel, and means on each of said end plates defining a lug disposed adjacent to and inboard of said flange, said lugs being operative during centrifugally induced radially outboard displacement of said end plates to radially clamp said flange against said cylindrical shoulder and thereby provide a 360° seal radially outboard of each of said manifolds.

3. In a gas turbine rotor assembly including a wheel having a circumferential array of retention slots, a plurality of air cooled blades having bases disposed in respective ones of said retention slots, each of said bases cooperating with said respective ones of said retention slots in defining a plurality of manifolds supplied with pressurized air from a first side of said wheel, and a spacer disposed adjacent a second side of said wheel radially inboard of each of said manifolds and rotatable as a unit with said wheel, an end seal for each of said manifolds at said second side of said wheel comprising, a seal ring having an annular planar portion and an integral cylindrical flange disposed perpendicular to and radially outboard of said planar portion, said planar portion being disposed between said spacer and said wheel, means operative to axially clamp said spacer and said wheel thereby to tightly capture said planar portion therebetween so that contact is established between said seal ring and said wheel radially inboard of each of said manifolds and a 360° inboard seal is defined, means on said wheel and on each of said blade bases defining a continuous radially inwardly facing cylindrical shoulder disposed radially outboard of each of said manifolds, said flange being disposed radially inboard of and adjacent said cylindrical shoulder, a plurality of end plates supported on said wheel adjacent said second side and radially outboard of said spacer and cooperating in defining an annular barrier to passage of a motive fluid extending completely around said wheel, each of said end plates being supported on said wheel for limited centrifugally induced radially outward displacement during rotation of said wheel, and means on each of said end plates defining an integral lug having a shoulder disposed adjacent to and radially inboard of said cylindrical flange, each of said lugs being operative during centrifugally induced radially outward displacement of said end plates to radially clamp said flange between said cylindrical shoulder and said lug shoulders and thereby provide a 360° seal radially outboard of each of said manifolds.

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